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Graphic technology — Determination of rheological properties of paste inks and vehicles by the falling rod viscometer

*Technologie graphique — Détermination des caractéristiques rhéologiques
des encres et excipients projetés, à l'aide d'un viscosimètre à tige
tombante*



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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12644 was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

Annex A forms an integral part of this International Standard.

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Graphic technology — Determination of rheological properties of paste inks and vehicles by the falling rod viscometer

1 Scope

This International Standard specifies the procedure for determining the viscosity and yield value of paste inks and vehicles which are unreactive under normal room conditions.

It is applicable to inks in the apparent viscosity range of 2 Pa · s to 200 Pa · s.

2 Definitions

For the purposes of this International Standard, the following definitions apply.

2.1 viscosity: Measure of the internal friction of a liquid in motion. The viscosity is generally defined as the ratio of the shear stress (2.2) to the shear rate (2.3):

$$\eta = \frac{\sigma}{\dot{\gamma}} \quad \dots (1)$$

2.2 shear stress, σ : Force per area in a direction parallel to the applied force. Unit: Pa.

NOTES

1 For the falling rod viscometer, the shear stress is proportional to the total weight of the rod and the weight loads in accordance with the equation

$$\sigma = \frac{W}{A} = \frac{mg}{2\pi rl} \quad \dots (2)$$

where (see figures 1 and 2)

- σ is the shear stress;
- W is the total weight of the rod and the weight loads;
- A is the apparent shearing area;
- g is the gravitational acceleration;
- m is the total mass;
- r is the radius of the rod;
- l is the length of the aperture.

2 The shearing length of the aperture of a falling rod viscometer usually contains both a tapered and a parallel section; therefore, it is understood that A is not the true shearing area but an apparent shearing area.

2.3 shear rate, γ : Velocity gradient through a stressed liquid in a direction perpendicular to the shearing area. Unit: s^{-1} .

NOTE — For the falling rod viscometer, γ is inversely proportional to all fall time according to the equation

$$\gamma = \frac{L}{r \cdot \ln(R/r) \cdot t} \quad \dots (3)$$

where

- γ is the shear rate;
- L is the falling distance of the rod;
- r is the radius of the rod;
- R is the radius of the aperture;
- t is the fall time.

If the ratio of the radii of the rod and aperture is close to unity, the term may be simplified to

$$\gamma = \frac{L}{st} \quad \dots (4)$$

where s is the thickness of the ink in the nip determined by the difference between radii of the aperture and of the rod.

2.4 apparent viscosity, η_a : Ratio of the shear stress σ to the shear rate γ for a given shear stress or shear rate. Unit: $\text{Pa} \cdot \text{s}$.

2.5 Newtonian liquid: Liquid whose shear stress is proportional to shear rate.

2.6 non-Newtonian liquid: Liquid whose shear stress is not proportional to shear rate.

NOTES

- 1 There are two types of non-Newtonian liquids: With shear thickening liquids, the viscosity increases with shear rate; with shear thinning liquids, the viscosity decreases with shear rate.
- 2 If the viscosity of a liquid decreases with application of steady mechanical stress from a value at the state of rest to a final value and increases again if the stress ceases, the liquid is called thixotropic.

2.7 flow curve: Graph of the shear stress σ as a function of the shear rate γ or vice versa.

2.8 Casson model (see A.1): Flow model which assumes a non-linear increase of shear stress σ with increasing shear rate γ . A minimum stress σ_0 is required to initiate flow.

2.9 Bingham model (see A.2): Flow model which assumes a linear increase of the shear stress σ with increasing shear rate γ . A minimum stress σ_0 is required to initiate flow.

2.10 Power Law model (see A.3): Flow model which assumes an increase of the shear stress σ of a liquid proportional to the N th power of the shear rate γ .

2.11 yield stress, σ_0 : Minimum stress required to initiate flow of a liquid. Unit: 1 Pa.

2.12 pseudo yield stress, σ_y : Shear stress at a defined low shear rate when applying the Power Law model, typically to $2,5 \text{ s}^{-1}$.

2.13 reference temperature: Temperature (25 °C) for which all results are reported. Unit: °C.

NOTE — Measurements made at temperatures different from this temperature are corrected (see 6.2.2).

2.14 test temperature: Actual temperature of the aperture ring during measurements. Unit: °C.

2.15 shortness ratio: Ratio of yield stress or pseudo yield stress to the apparent viscosity. Unit: 1 s⁻¹.

3 Test method

3.1 Principle

The principle of this test is the measurement of the relative velocity between a vertical rod and an aperture ring. The bottom of the rod is inserted into the aperture. The gap is filled with the test fluid, which is sheared when the rod falls.

By loading the rod with different load weights, different shear rates are obtained. By applying linear regression methods to the measured fall times as a function of load weight, the viscosity and the yield stress can be calculated.

3.2 Apparatus

3.2.1 Falling rod viscometer

The viscometer consists of

- a cylindrical rod (figure 1) made from metal or any other hard material. In order to obtain comparable values for shear stress and resulting shear rate the mass of the steel rod should be (132 ± 1) g.
- a metal ring (figure 2) with a defined cylindrical or conical aperture. The ring is fixed on a support and should be temperature controlled. Since the diameter of rod and aperture are critical they are manufactured within low tolerances. These dimensions shall be supplied by the manufacturer. To minimize possible gap differences, only matching sets of rod and aperture ring shall be used.
- load weights to be loaded on top of the rod. Series of load weights are combined to sets. Sets of load weights with the following masses should be used:

A:	5 000,	4 000,	3 000,	2 000,	1 000
B:	3 000,	2 000,	1 500,	500	
C:	1 500,	1 000,	800,	500	
D:	800,	600,	400,	200	
E:	400,	300,	200,	100	
F:	200,	100,	50,	0	

The tolerance for the masses of load weights shall be $\pm 0,2$ g;

- a designated measuring distance marked on the strut. The tolerance shall be $\pm 0,2$ mm. Sensors may be placed at the marks.
- a levelling device.
- a timing device. The tolerance shall be $\pm 0,1$ s (should be $\pm 0,01$ s).